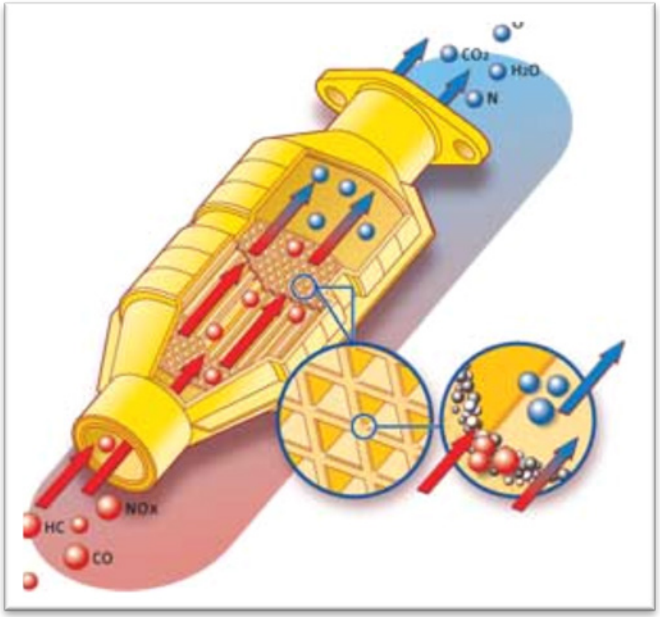
Exhaust system



SUZUKI TRAINING ACADEMY

Engine Auxiliary Systems
Course code: EN05

Student training manual
Suzuki Online Training

Foreword

This training manual contains basic information on the exhaust system. We will study exhaust system components and their functions, the catalytic convertor and exhaust gas analysis using the exhaust gas analyzer.

After your have completed this course, also complete the relevant section in the “Practical Activities Student Workbook” and the online test.

Smart manuals

Some sections of this training manual contain videos with detailed information on the topics you are studying. If you are studying this training manual on a PC, look out for the “green play video” symbol on any part of this training manual, click on the green button to watch a video providing you with detailed information on that topic. Note: Internet connection required.

This document is intended solely for training purposes only. All vehicle repairs and adjustments must be carried out according to the procedures stipulated in current service manuals and technical bulletins.

Suzuki Technician curriculum

This training manual is part of the Non Suzuki Technician to Suzuki Technician curriculum. The curriculum consists of the following modules:

1. GE01 Suzuki Introduction
2. GE02 Electrical and Electronics
3. Diagnostics
4. EN02 Engine Mechanical part I
5. En03 Engine Mechanical part II
6. EN04 Engine Mechanical part III
7. EN05 Engine Auxiliary systems
8. DS01 Driveshaft/Axle
9. DS02 Driveshaft/Axle transfer case
10. BR02 Brake control systems
11. Manual transmission / transaxle
12. CS02 Control system / body electrical
13. CS03 Communication / bus systems

You are currently studying EN05 Engine Auxiliary Systems. This module consists of the following courses:

- Charging systems
- Starting systems
- Exhaust system

Click on the other training modules to view their training contents.

Table of contents

Exhaust system

In this lesson, we will study the basic function of the exhaust system and its components.

Objectives

At the end of this lesson, you will be able to:

- Describe the function of the exhaust system
- Name the basic components making up the exhaust system.
- Describe the functions of individual exhaust gas components
- Describe the functions of the catalytic converter

Function

The main purpose of the exhaust system is to:

- Extract exhaust gases from the exhaust manifold and discharge them off at a suitable place in the vehicle.
- Reduce/muffle exhaust gas noise produced during the combustion process of the internal combustion engine.
- Reduces environmental pollutants in the exhaust gases

Exhaust system components

The exhaust system is made up of the following components: (figure 1)

[1] Exhaust manifold
[2] Warm-up three-way catalytic converter
[3] Catalytic converter
[4] Exhaust pipe No.1
[5] Exhaust pipe No.2
[6] Exhaust muffler 1
[7] Exhaust muffler 2
[8] Front muffler
[9] A/F sensor
[10] HO2S

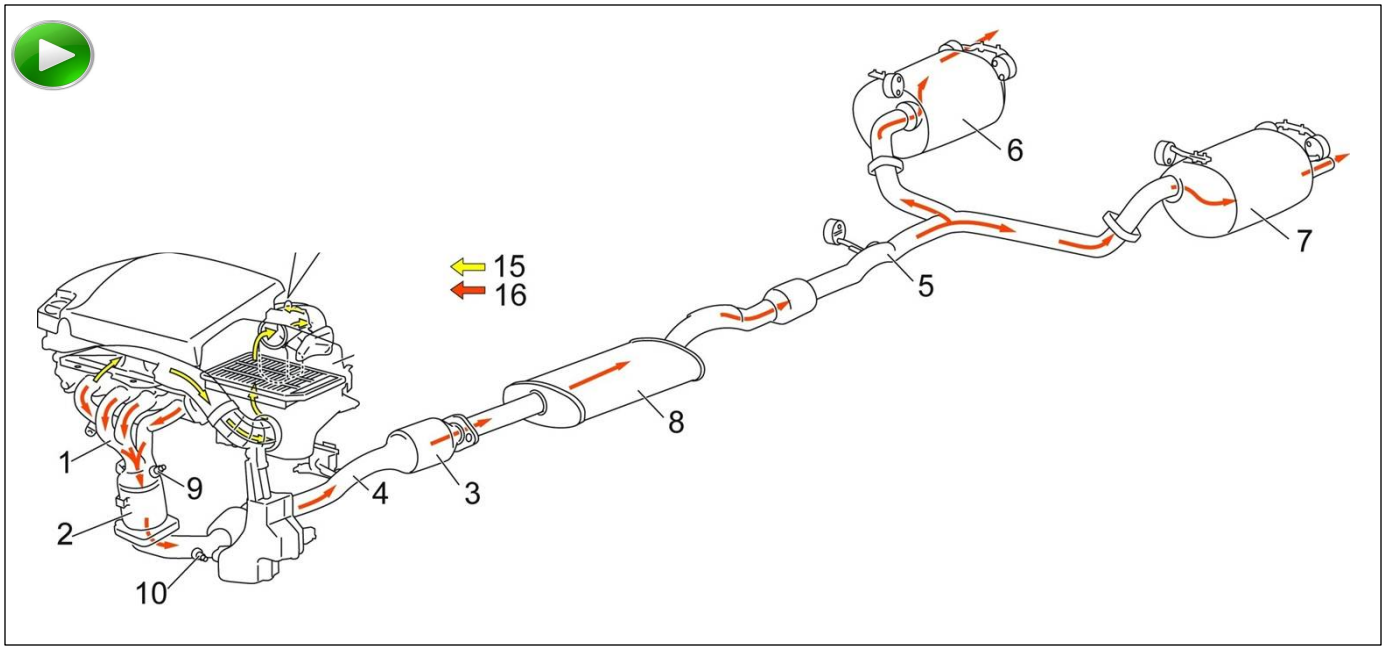


Figure 1- Exhaust system components (Suzuki Kizashi)

Exhaust manifold

The exhaust manifold is mounted directly onto the cylinder head exhaust side and it is made of pipes that cover the openings of the exhaust ports on the cylinder head. Its main function is to extract the exhaust gases and channel them into the exhaust pipes.

The exhaust system is usually made of cast iron, stainless steel or light weight steel tubing. A gasket is used between the cylinder head and the exhaust manifold to prevent leakage.

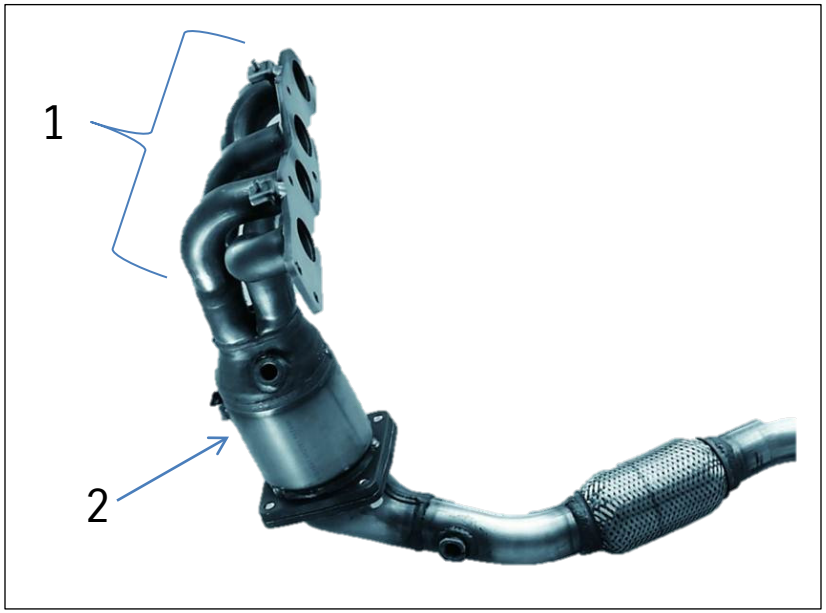


Figure 2- Exhaust manifold (1) and catalytic converter (2)

Catalytic Converter

Figure 3 – Catalytic converter

Function

The catalytic converter is an emission control device added to the exhaust system to lower the levels of Hydrocarbon (HC), Carbon Monoxide (CO), and Oxides of Nitrogen (NOx) pollutants in exhaust gases.

A catalyst in the convertor chemically treats pollutants in the exhaust gases converting them to less harmful substances. A catalyst causes a chemical reaction but after the reaction it remains unchanged.

Design

The catalytic converter has a ceramic core, housed in a stainless steel shell. The core contains many small passages through which the exhaust gas pass. A thin coating of aluminum oxide covers these passages and has a rough surface and is designed to provide a large surface area in the passages where the exhaust gasses pass.

Metal core

This is made of finely corrugated 0.05mm thick metal foil, wound around and brazed in a high temperature process. It offers extremely low resistance to the flow of the gases.

Ceramic core

The ceramic monolith is made of cordierite. It has an extremely high stability to temperature and thermal shock but cannot be installed directly to the metal housing. A special expanding mat is necessary to compensate for the difference between the thermal-expansion coefficients of steel and ceramic and also protects the ceramic monolith against shocks.

Catalyst

The catalyst is made of a precious metal. Platinum is widely used as a catalyst in the catalytic converter. The harmful exhaust gasses react with the platinum to produce less harmful gases. Platinum and palladium accelerate the oxidation of HC and CO, while rhodium is responsible for reducing NOx.

Two way catalytic convertors

The two way catalytic convertor has two simultaneous tasks. In this process, Oxygen (O2) reacts with Carbon monoxide (CO) to produce carbon dioxide (CO2). The Oxygen also reacts with hydrocarbons (un-burnt or partially burnt fuel) to produce carbon dioxide (CO2) and water (H2O). Two way catalytic convertors are unable to reduce Nitrogen Oxides.

Three-Way Catalytic converter

In addition to the two tasks performed by the Two-way catalytic converter, the Three-Way Catalytic (TWC) convertor also uses carbon monoxide (CO) to convert Nitrogen Oxides (NOx) to Nitrogen (N_2) and Carbon dioxide (CO_2)

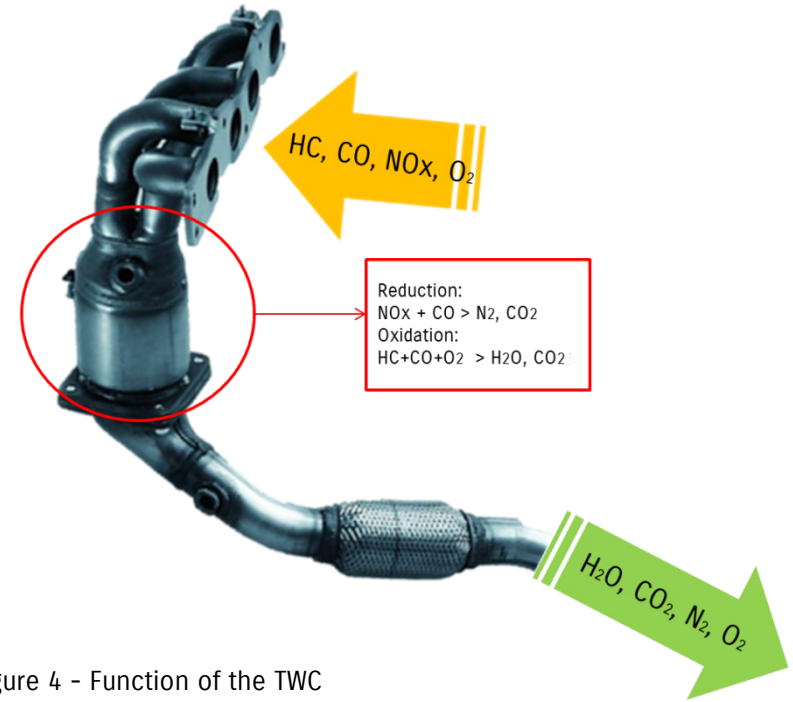


Figure 4 - Function of the TWC

Operating temperature of the catalytic converter

Catalytic converters do not start significant conversion until they have reached a specific temperature.

On the TWC's this is approx. 300ºC. Ideal conditions for high conversion rates are achieved at 400ºC to 800ºC.

figure 5 - Exhaust gas oxygen sensor

Oxygen sensors

Oxygen sensors are installed up-stream and down-steam of the catalytic converter and measure the amount of oxygen content in the exhaust gases. The upstream oxygen sensor signal is used by the ECM to regulate very precisely the air/fuel mixture for combustion to the value Lambda = 1. The downstream oxygen sensor is used by the ECM to determine the efficiency of the catalytic converter.

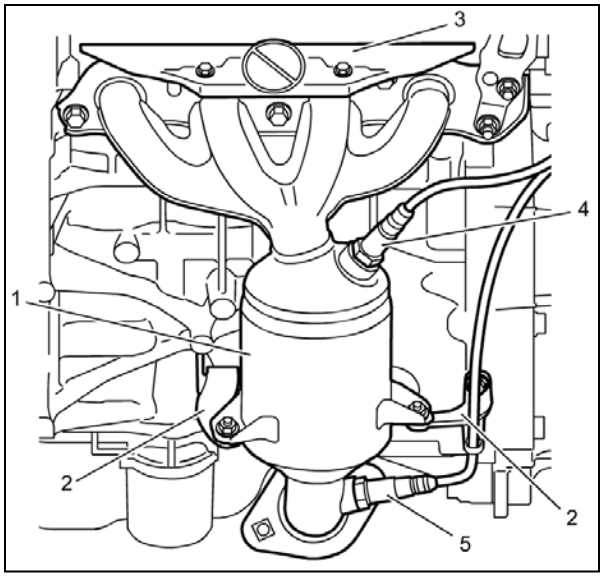


Figure 6 - Location of exhaust gas oxygen sensors

[1] Catalytic Converter
[4] Up-stream oxygen sensor (A/F sensor)
[5] Down-stream oxygen sensor (H2OS)

Muffler

Exhaust mufflers smooth out exhaust gas pulsations and make them as inaudible as possible. There are essentially two physical principles involved: reflection and absorption.

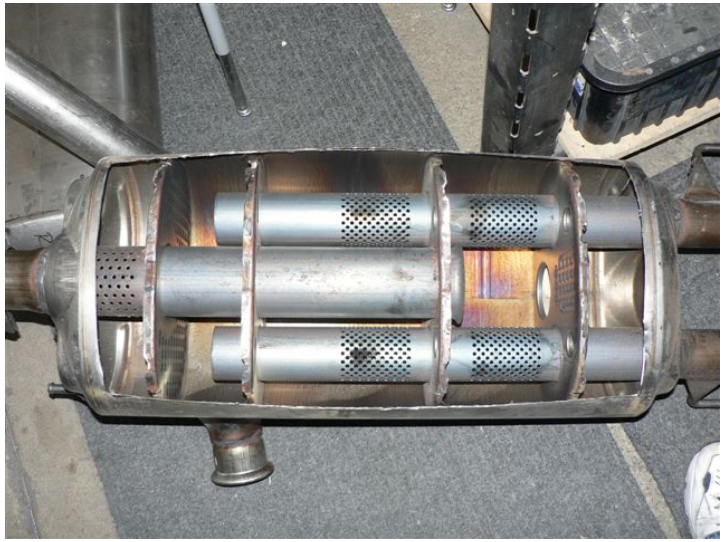


Figure 5 – Exhaust muffler

Connecting pipes

These are used to connect the exhaust components together e.g. connecting the catalytic converter tot the muffler. At some instances, flexible pipes are used to allow engine movement and reduce vibrations without passing it to the rest of the exhaust, especially in front wheel drive vehicles. It also helps with alignment of the pipes.

The complete exhaust system is secured to the vehicle using brackets and elastic mounting elements.

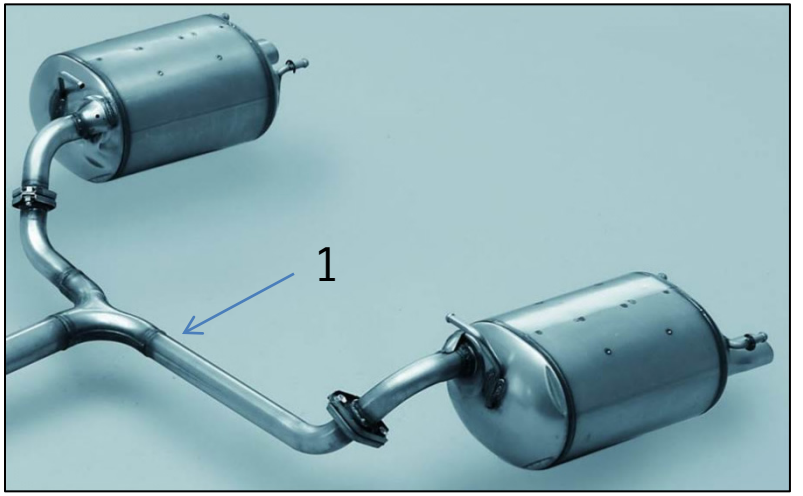


Figure 6 – Dual exhaust mufflers (Suzuki Kizashi)

[1] Connecting pipe

Exhaust gas composition

In this lesson, we will study composition of the exhaust gases and the exhaust gas analyzer.

Objectives

At the end of this lesson, you will be able to:

- Name the gases that can be found in exhaust gases up-stream of the catalytic converter
- Name the gases that can be found in the exhaust system down-stream of the catalytic convertor
- Describe the effect of the stoichiometric ratio in the composition of exhaust gases.
- Interpret exhaust gases

The relevant gases and substances

Carbon Monoxide (CO)
Hydrocarbons (HC)
Nitrogen Oxides (NOx)
Nitrogen dioxide (NO2)
Nitric oxide (NO)
Hydrocarbons (HC)
Oxygen (O2)
Carbon dioxide CO2)
Benzene (A hydrocarbon)
Lead (Pb)

Effects of rich and lean mixtures on exhaust gases

The concentrations of pollutants in the untreated exhaust gas (upstream of the catalytic converter) largely depend on the air/fuel ratio. A mixture composition in the stoichiometric ratio λ = 1 results in exhaust gases that have very low levels of pollutants. The ideal theoretical stoichiometric ratio is 14:1 (14 parts of air mixed with 1 part of fuel).

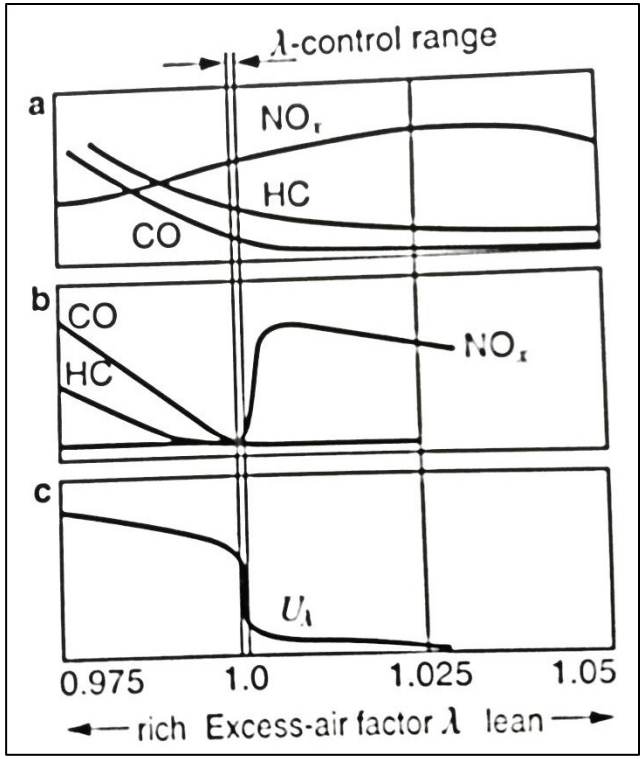


Figure 1 – Effects of air/fuel mixture on exhaust gases

[a] Exhaust gases upstream of catalytic converter
[b] Exhaust gases downstream of catalytic converter
[c] Electrical voltage of two step λ sensor

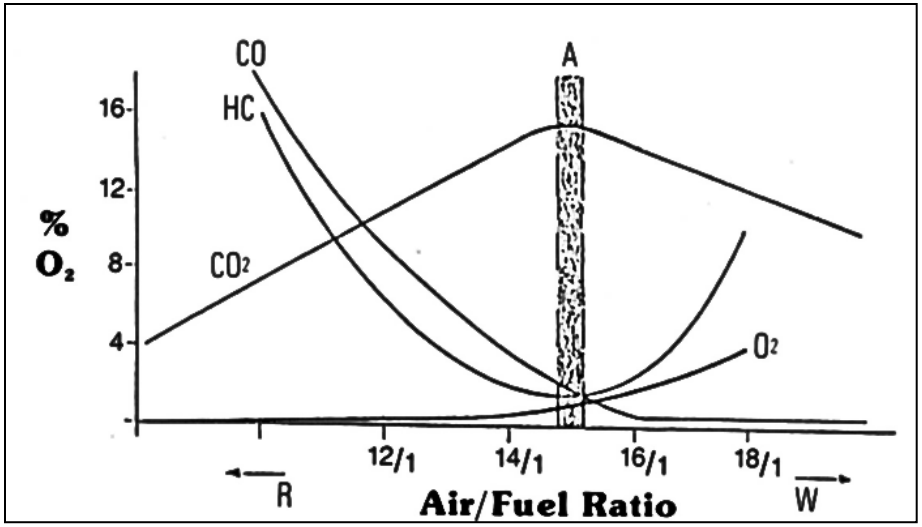
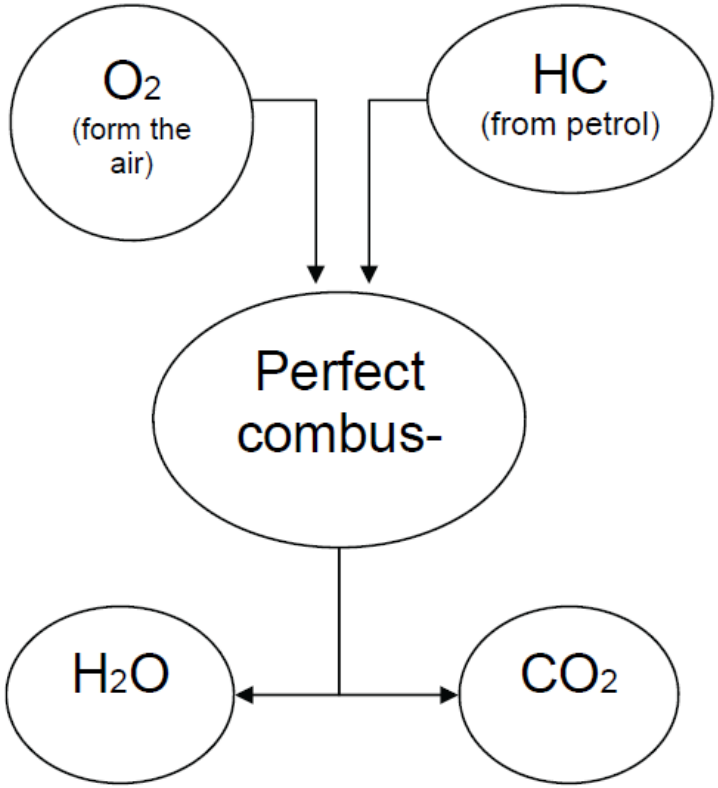


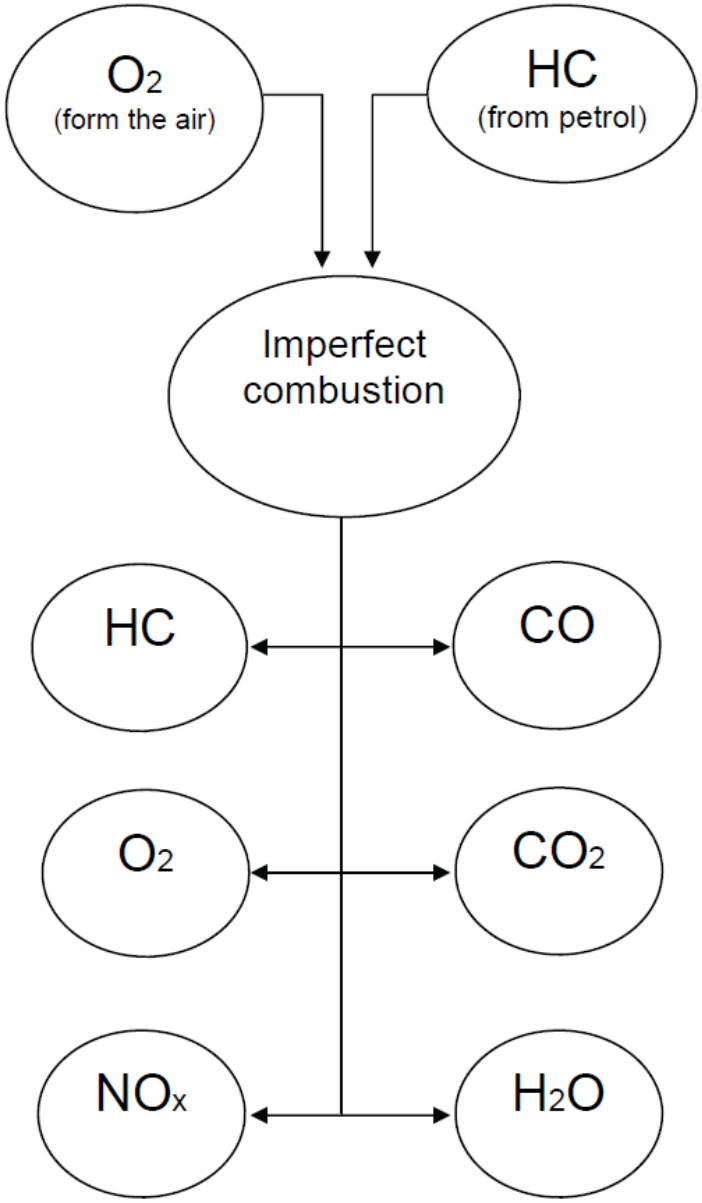
Figure 2 – O2 level against air/fuel ratio

[A] Stoichiometric band
[R] Rich
[W] Weak

The perfect combustion



The imperfect combustion



Composition of exhaust gases

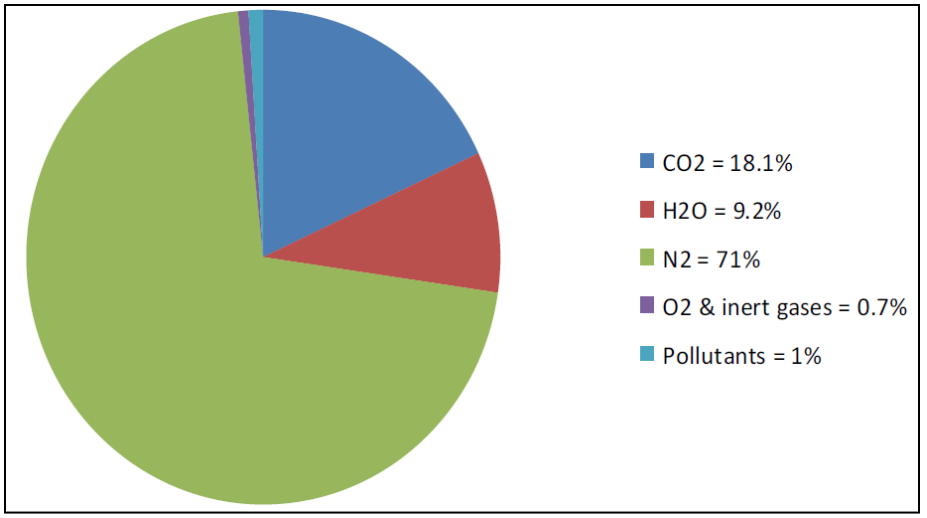


Figure 3 – Composition of exhaust gases

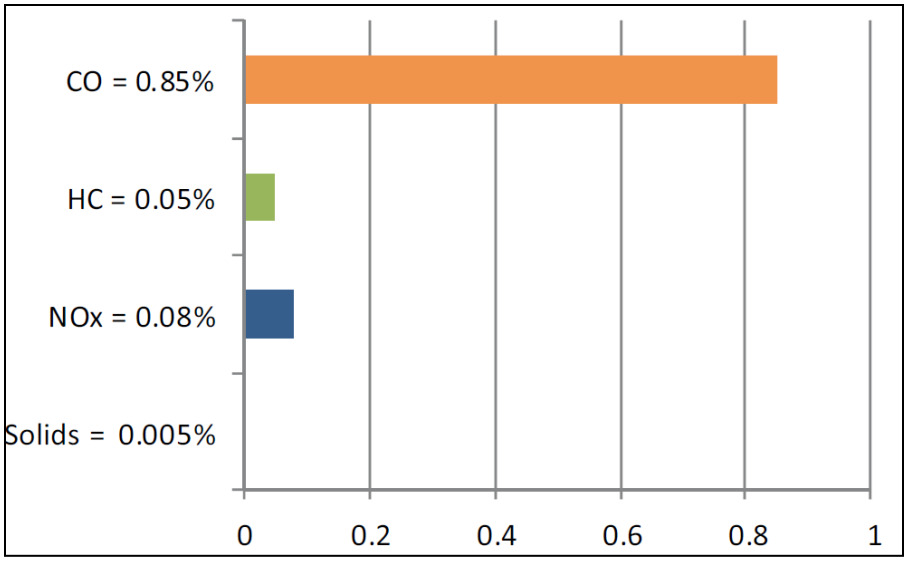


Figure 4 – Composition of pollutants in exhaust gases

Exhaust gas analysis

Use of the exhaust gas analyzer can be helpful in troubleshooting both emissions and drivability concerns (engine malfunctions).

Figure 5 – Exhaust gas analyzer

Diagnosis using exhaust gas analysis

In troubleshooting, always remember the combustion chemistry:

Fuel (Hydrogen, carbon, sulfur) + air (Nitrogen, oxygen) = Carbon dioxide + water vapor + oxygen + carbon monoxide + hydrocarbon +oxides of nitrogen +sulfur oxides

In any diagnosis of emission or drivability related concerns, ask yourself the following questions:

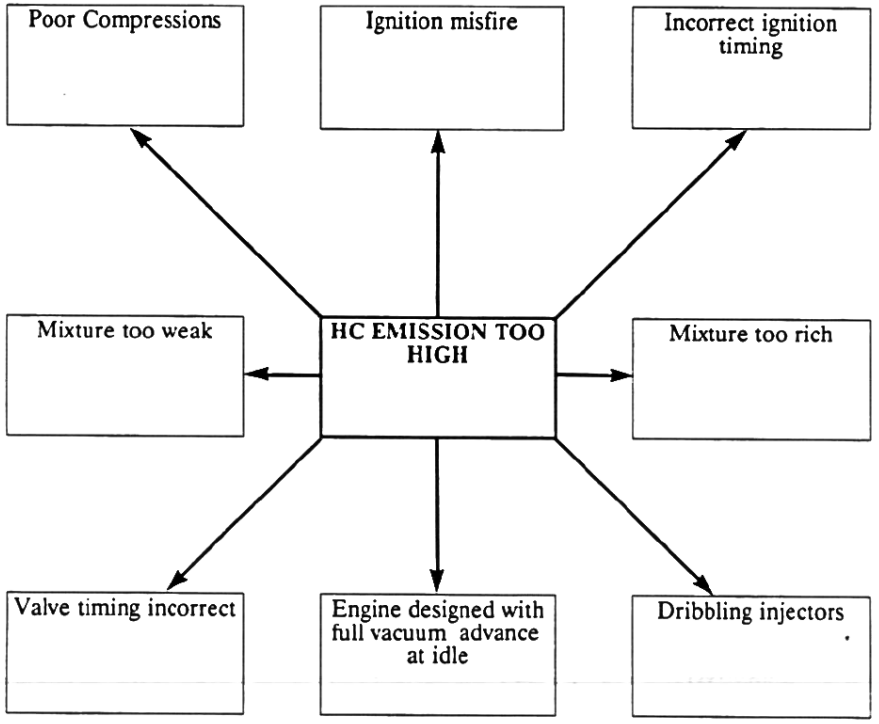
- What is the symptom?
- What are the baseline exhaust readings? At idle, 2500 rpm, acceleration, deceleration, light load cruise, load.
- Which sub-systems or components could cause the combination of exhaust gas readings measured?

Hydrocarbon (HC) levels

HC is un-burnt fuel that remains as a result of misfire. When combustion doesn't take place or only part of the air/fuel charge burns, hydrocarbon levels go up. The hydrocarbons are measured by an exhaust analyzer in parts per million (ppm).

The following figures are offered as a guide:

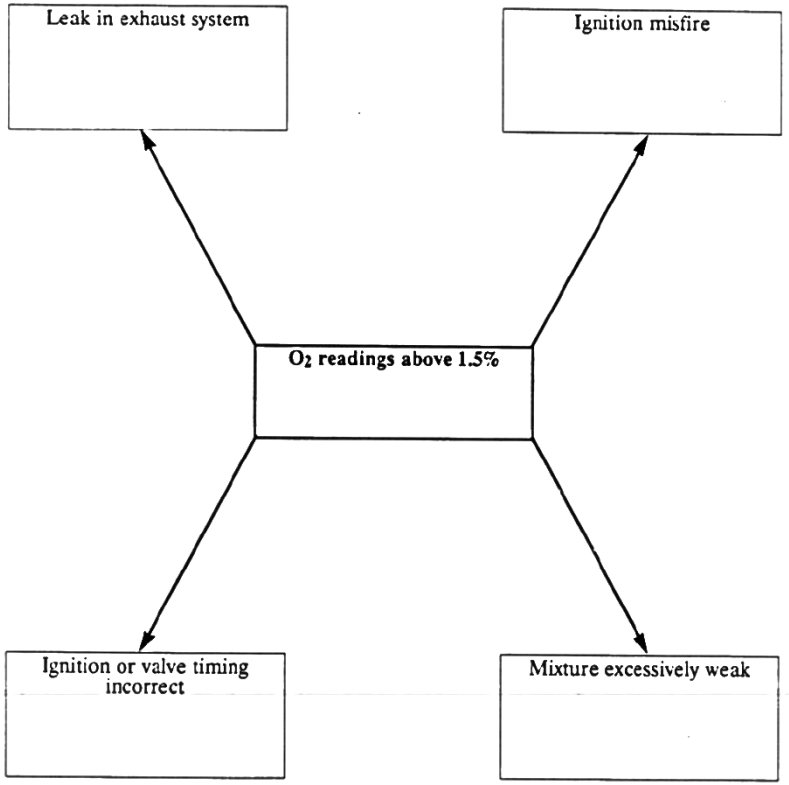
	Petrol injection models	Carburetor models
At idle speed	Below 100 ppm	Below 300 ppm
At 3000 rpm	Below 50 ppm	Below 100 ppm



Oxygen (O_2) Levels

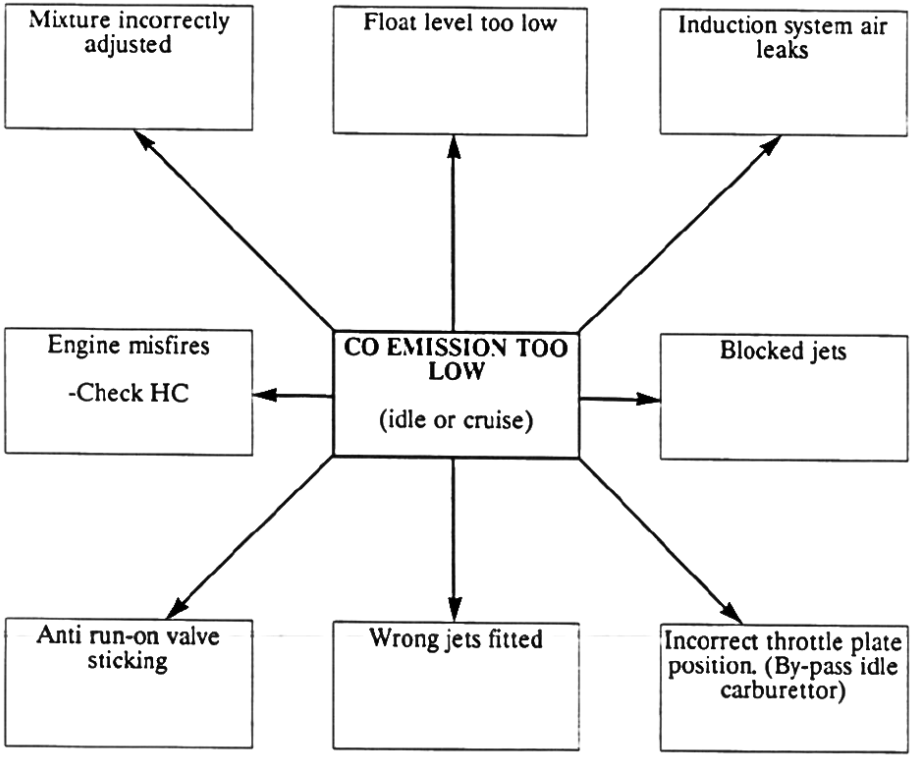
Oxygen is measured by the exhaust gas analyzer in percentages (%). The amount of oxygen produced by the engine is affected by how close the air/fuel ratio is to stoichiometry. As the mixture goes lean, oxygen increases and it decreases as the mixture goes rich.

The normal readings are below 1.5%

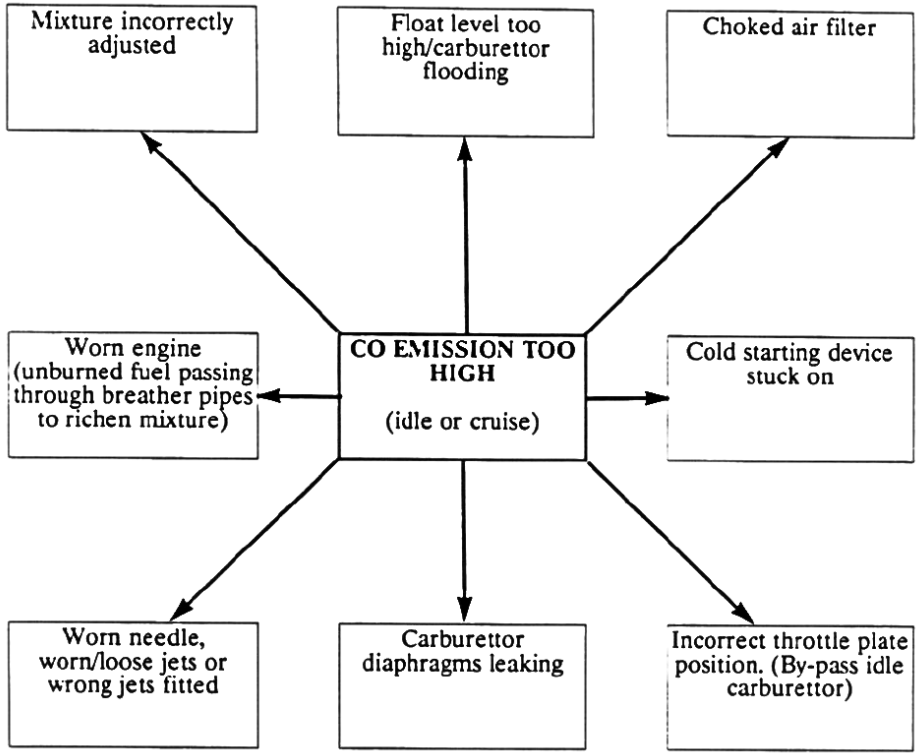


Carbon Monoxide (CO) level
Carburetor engines

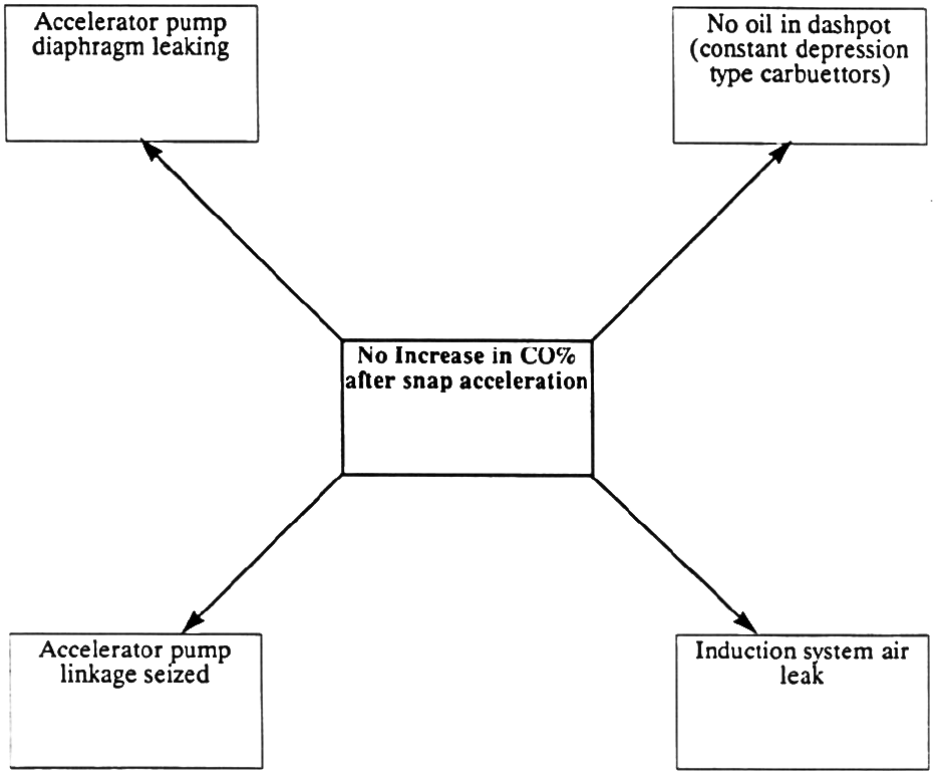
Carbon monoxide is measured by the exhaust analyzer in % or parts per hundred. CO is a byproduct of combustion, therefore, if combustion does not take place, carbon monoxide will not be created.



Carbon Monoxide (CO) level
Carburetor engines (continued)



Carbon Monoxide (CO) level
Carburetor engines (continued)



Carbon Monoxide (CO) level
Petrol injected engines

The measure of CO percentage is used to assess the mixture strength of the vehicle. The lower the CO level the weaker the mixture and conversely the higher the CO level the richer the mixture. The CO level can be assessed under three different operating conditions: Idle, acceleration and cruising.

Idle CO

The CO is measured at the correct idle speed for the vehicle as specified by the service manual and compared with the manufacturers recommended figures.

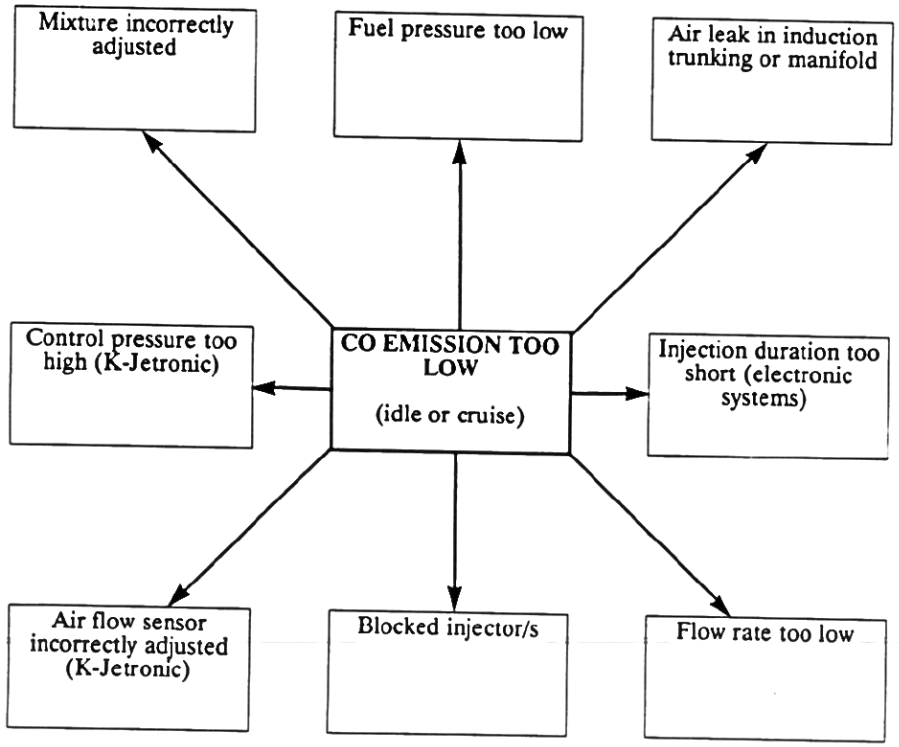
Acceleration CO

This can be measured by snapping open the throttle once and watching the CO level increase.

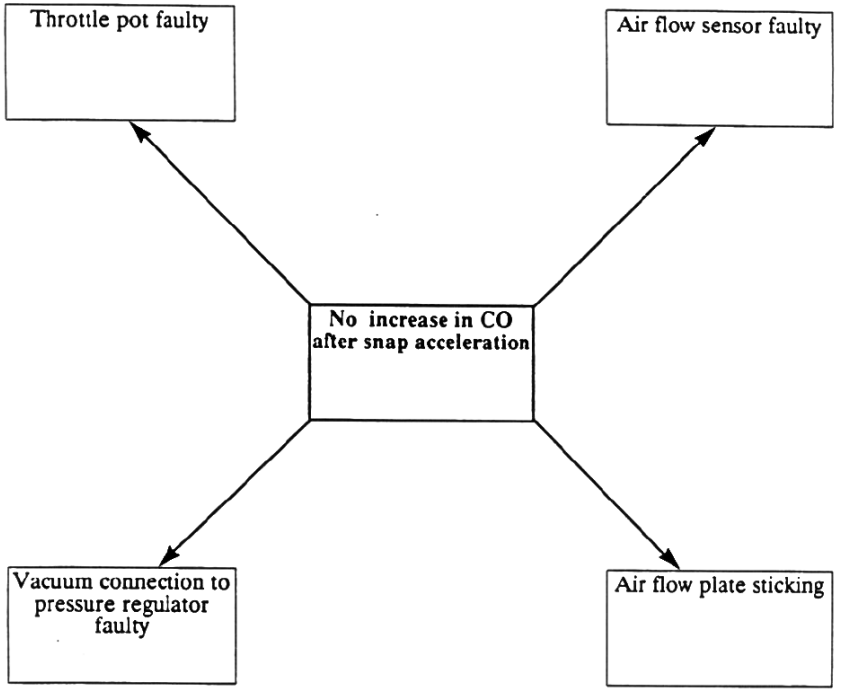
Cruising CO

This can be measured by holding the engine at a steady 3000 rpm. The readings should range between 0% and 1%, on electronic systems and 0% and 2.5% on the K-Jetronic (Mechanical) system

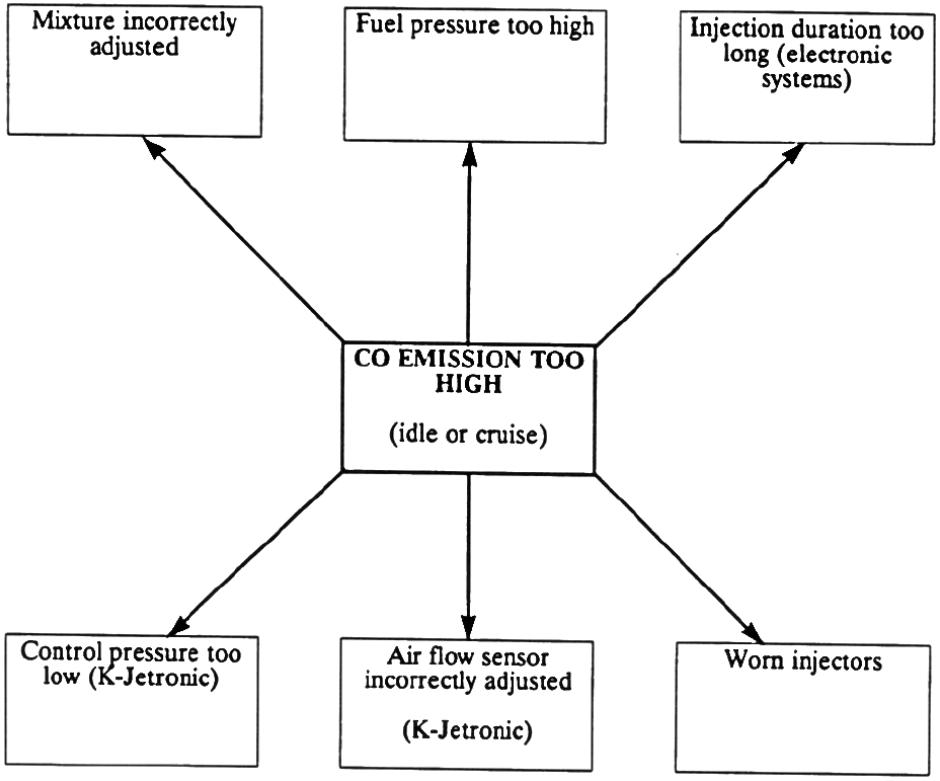
Carbon Monoxide (CO) level
Petrol injected engines (continued)



Carbon Monoxide (CO) level
Petrol injected engines (continued)

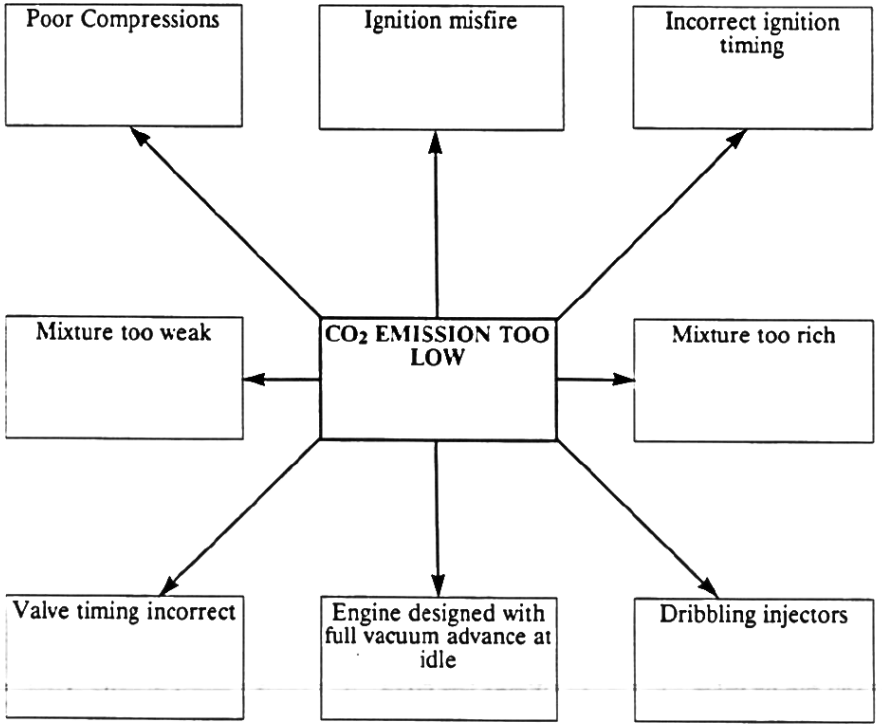


Carbon Monoxide (CO) level
Petrol injected engines (continued)



Carbon Dioxide (CO2) level

Carbon dioxide is a byproduct of efficient and complete combustion. Near perfect combustion will result in carbon dioxide levels which approach the theoretical maximum of approximately 15.5%. Carbon dioxide levels are affected by air/fuel ratio, spark timing and any other factors which affect combustion efficiency. The minimum level should not be below 10%.



Suzuki exhaust emissions symptom diagnosis

Excessive hydrocarbon (HC) or carbon monoxide (CO) emission	Faulty spark plug
	Faulty ignition coil with ignitor
	Low compression
	Lead contamination of three-way catalytic converter
	Faulty evaporative emission control system
	Fuel pressure out of specification
	Closed-loop system (A/F feedback compensation) fails (faulty TP sensor, poor performance of ECT sensor or MAF sensor)
	Faulty throttle body assembly
	Faulty APP sensor
	Faulty injector(s)
	Faulty ECM
	Engine not at normal operating temperature
	Clogged air cleaner
	Vacuum leak
	Camshaft position control system out of order
Excessive nitrogen oxides (NOx) emission	Improper ignition timing
	Lead contamination of catalytic converter
	Fuel pressure out of specification
	Closed-loop system (A/F feedback compensation) fails (faulty TP sensor, poor performance of ECT sensor or MAF sensor)
	Faulty throttle body assembly
	Faulty APP sensor
	Faulty injector(s)
	Faulty ECM
	Camshaft position control system out of order

Exhaust emissions analysis

The following photo shows the analysis of exhaust gases in a Suzuki Swift AZH414 with no engine malfunctions.

Figure 6 – Exhaust gas analysis, Suzuki Swift

CO = 0.00%
HC = 0 ppm
CO2 = 12.8%
O2 = 0.07%
λ = 1.003
Air/Fuel Ratio = 15.5

Summary

- A catalytic converter removes harmful pollutants from the exhaust gases though chemical reactions.
- Excess oxygen in the exhaust gas results in increase NOx.
- Oxygen reacts with the carbon monoxide and hydrocarbons to produce water and carbon dioxide.
- The carbon monoxide reacts with NOx to produce nitrogen and carbon dioxide.
- The exhaust mufflers are used to reduce exhaust noises generated during the combustion process.
- The upstream oxygen sensor is used by the engine control module correct the air/fuel mixture.
- The downstream oxygen sensor is used by the engine control module to monitor the efficiency of the catalyst.
- Exhaust gas analysis can be used to diagnose engine malfunctions.

Well done, you have now completed the “Exhaust system” training course!

Please complete the online exam.